Scaling Understanding up to Mental Spaces

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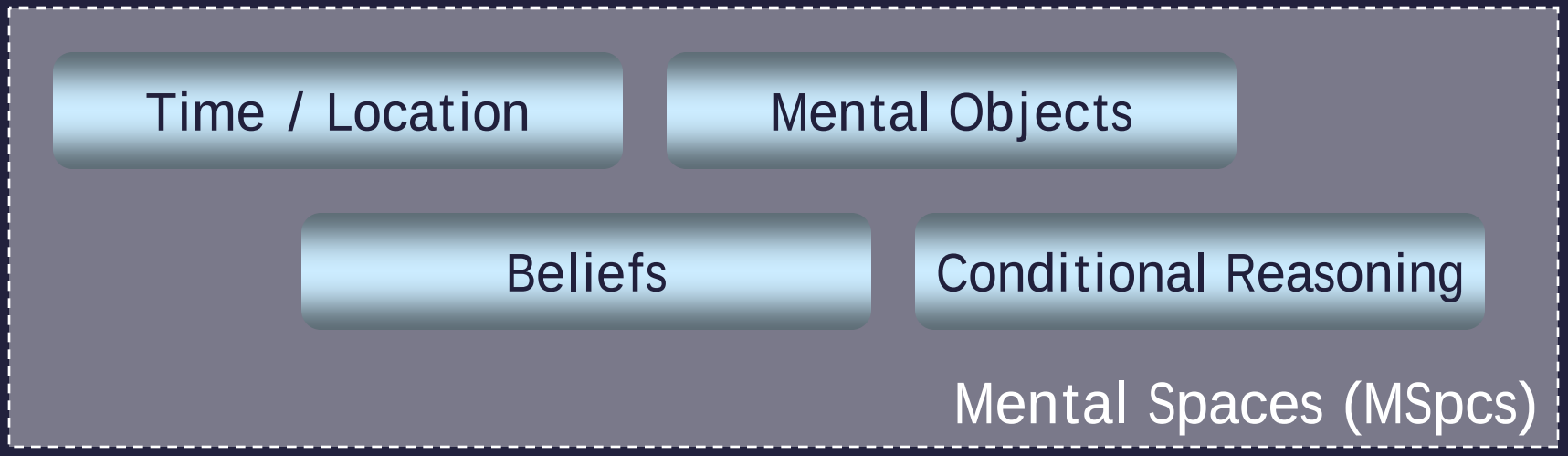
Complex Inference in Language

- Consider these sentences:
  - In 1950, the President was a baby.
  - In the movie, Tom Cruise became a samurai.
  - Harry thinks that Bill lied to him.
  - And if I'm elected those promises will be kept.



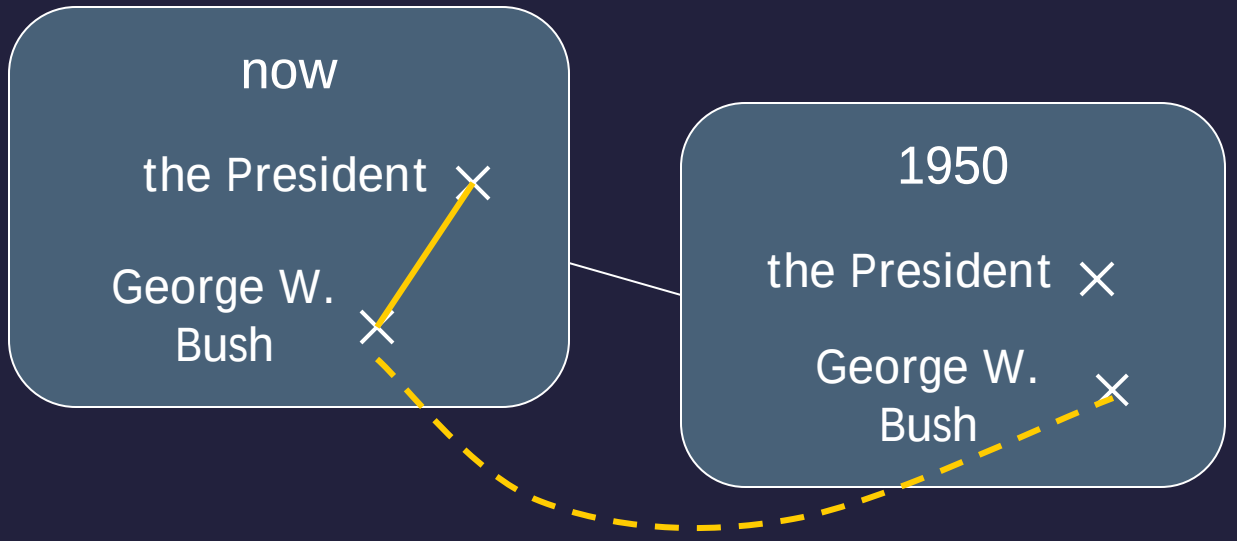
What are Mental Spaces?

- Fauconnier,1985
- Partial cognitive structures built up during discourse
- Keep track of entities and relations in different contexts
- Enable scalable reasoning in a partitioned large knowledge base
- The related linguistic phenomena are largely ignored in today's NLP systems

Mental Space Literature

- In 1950, the President was a baby.

space builder

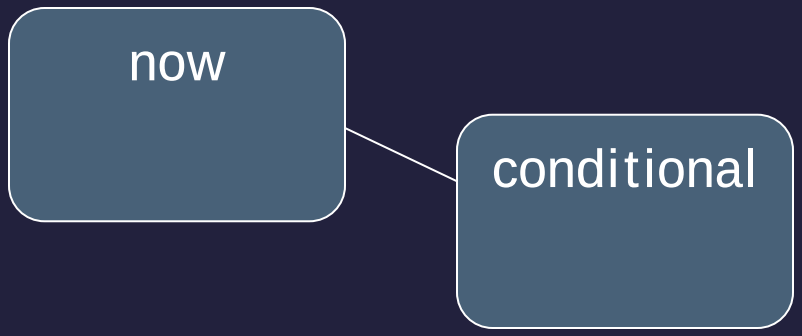


Spreading Principle:

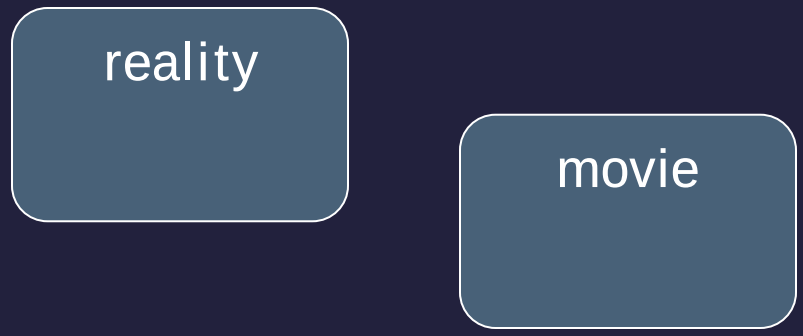
Relevant structure in a parent space can transfer to a child space unless explicitly contradicted by existing structure, and vice versa

Insufficient

- There is much to be gained from MSpc literature
- NOT formalized
- One rule for all types of spaces? not clear
- and how does inference transfer back?



some assumptions should carry over, esp for planning

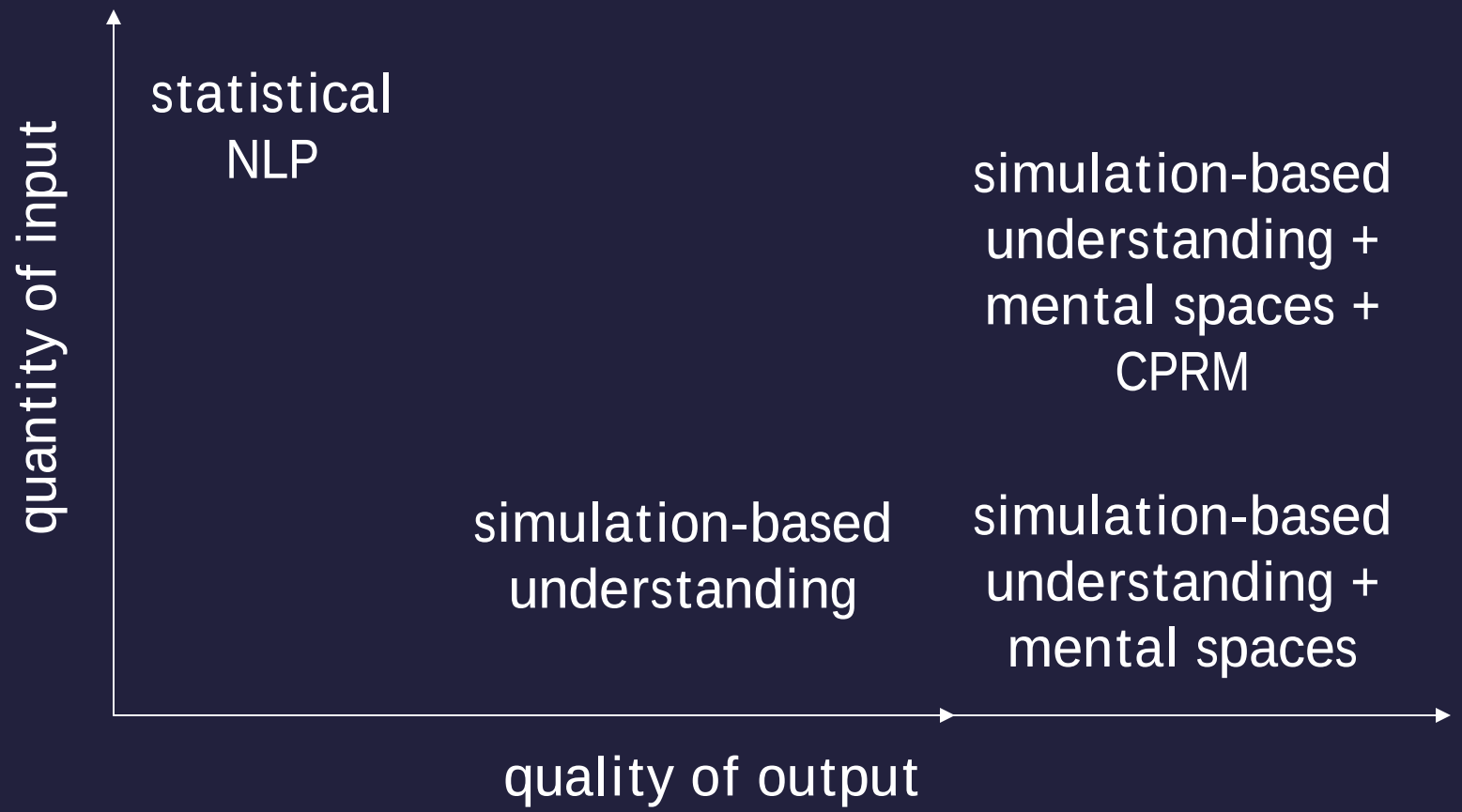


? ?

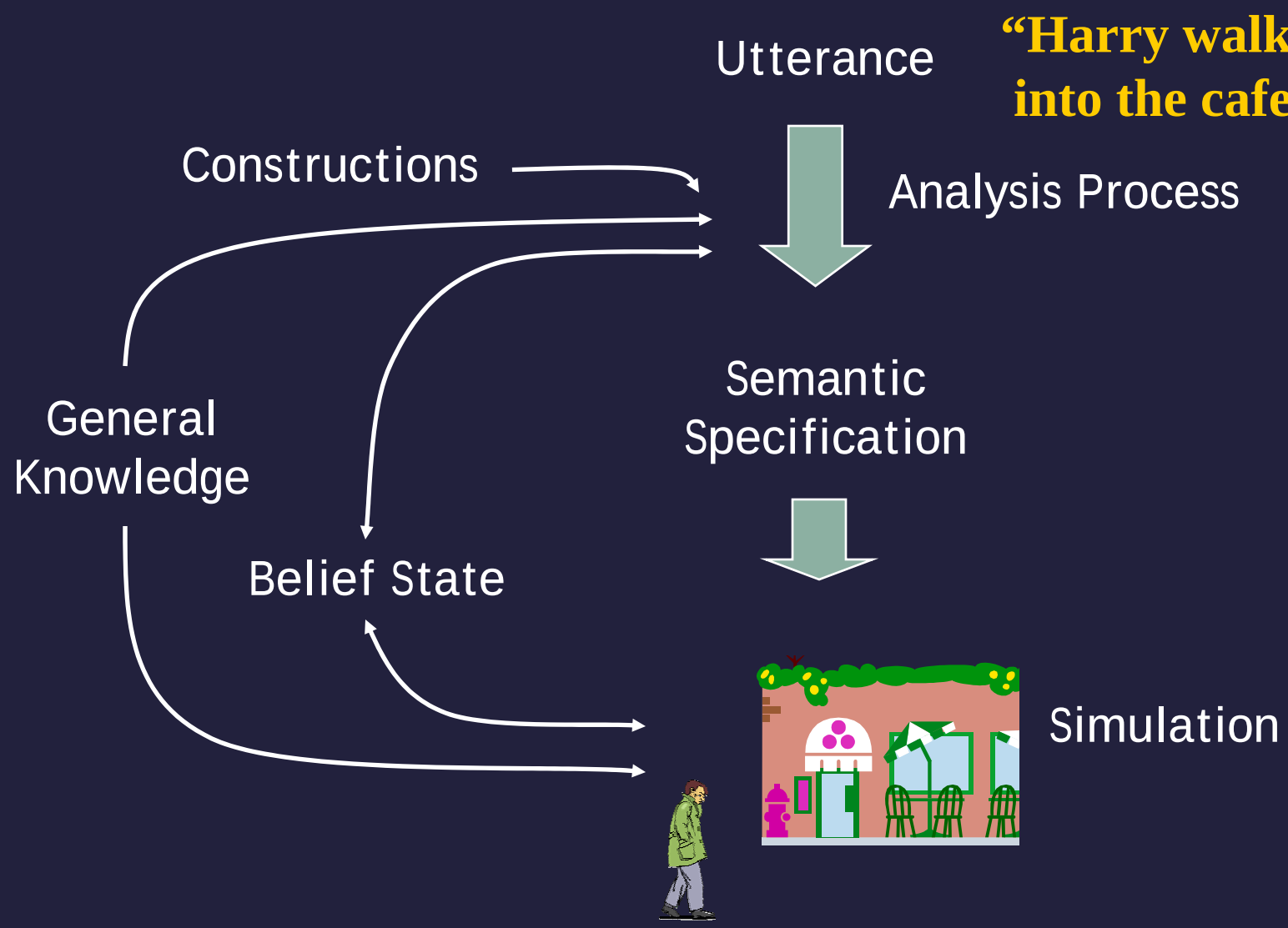
Talk Outline

- Introduction
- Simulation-Based Understanding Framework
- Representing Mental Spaces in ECG
- Inference with Mental Spaces
- Case Study: English Conditionals
- Conclusion

Scalability



Simulation-Based Understanding



Mental Spaces in ECG

- Simulation is dynamic
  - Executing X-schemas
  - Propagating belief updates
- Mental space is a partitioning of
  - Entities and relations
  - Contextual knowledge

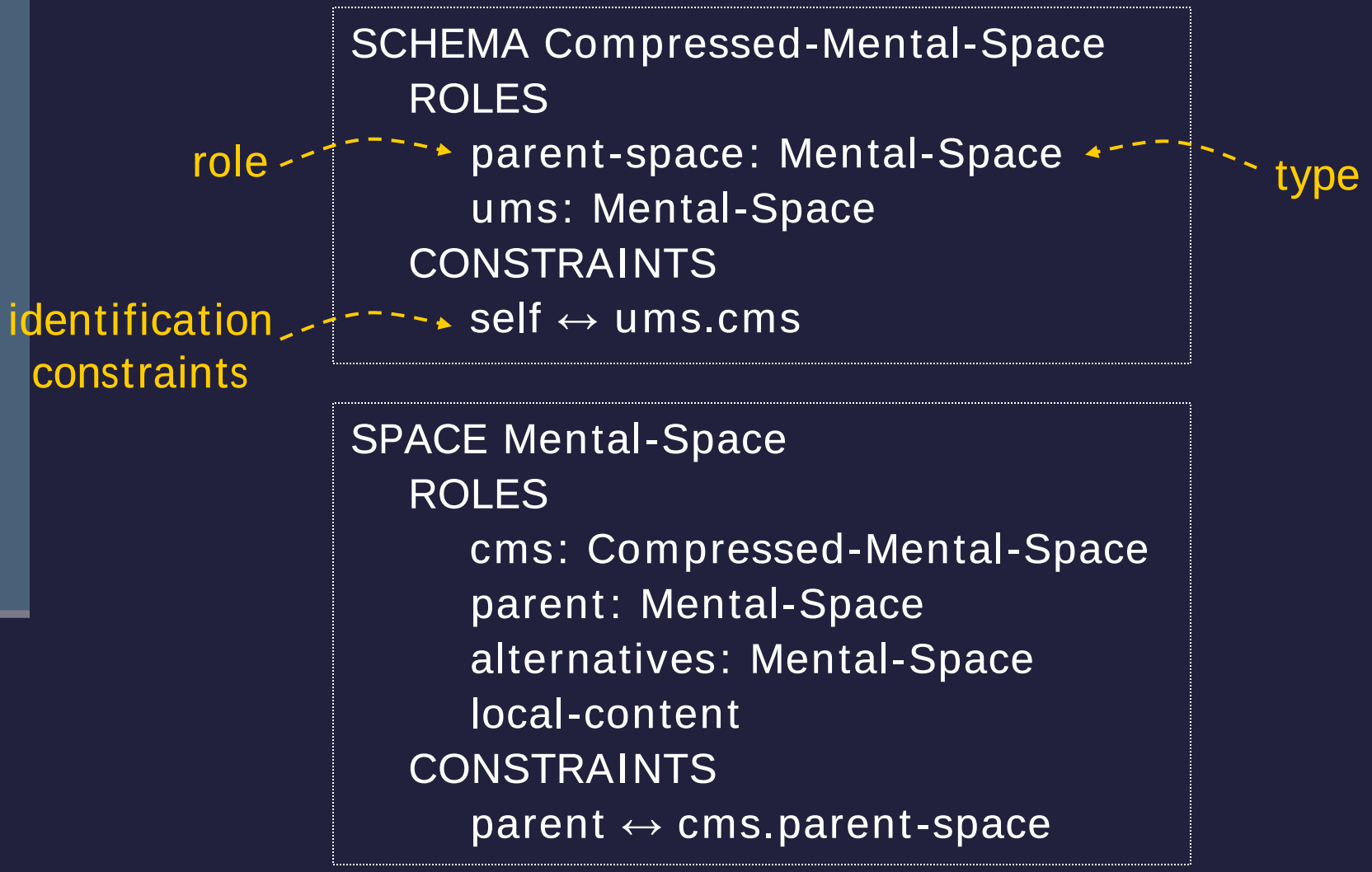
Each mental space is a separate thread of simulation,
i.e., separate belief network,
separate simulation trace

Avoiding Explosion of MSpcs

- Many things in a discourse can potentially be MSpcs
- New threads of simulation are expensive
- Levels of granularity
  - *The Last Samurai* is sitting on the shelf.
  - In the movie, Tom Cruise became a samurai.
- No need to build new thread until simulation demands it for inference

Each potential space-builder is represented at two levels of granularity:
(1) in schematic form and (2) as a full space

In ECG Representation



Adding Schemas to a Space

SCHEMA Cause-Effect
    ROLES
        cause: Predication
        effect: Predication
        local-to: Mental-Space

the space that this schema belongs to

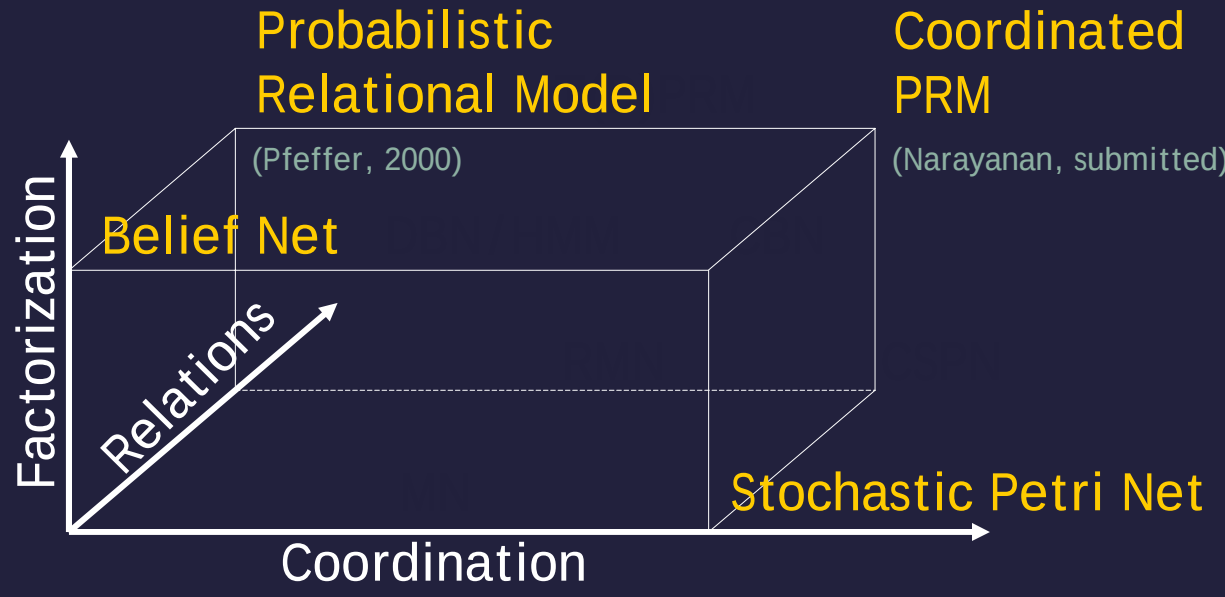
Inference with Mental Spaces

- Comparisons across spaces:
  - Plans for tomorrow have implications for actions today
  - Alternative scenarios
  - Counterfactual reasoning
- Inferences drawn in one space need to be selectively propagated to another

Two mental spaces can be related by:

1. shared assumptions (shared spaces)
2. direct influence (influence links)

CPRM Formalism



- Coordinated Probabilistic Relational Model (CPRM) formalism combines action execution and probabilistic relational inference
- Shared spaces: classes in CPRM
- Influence links: directed edges in CPRM

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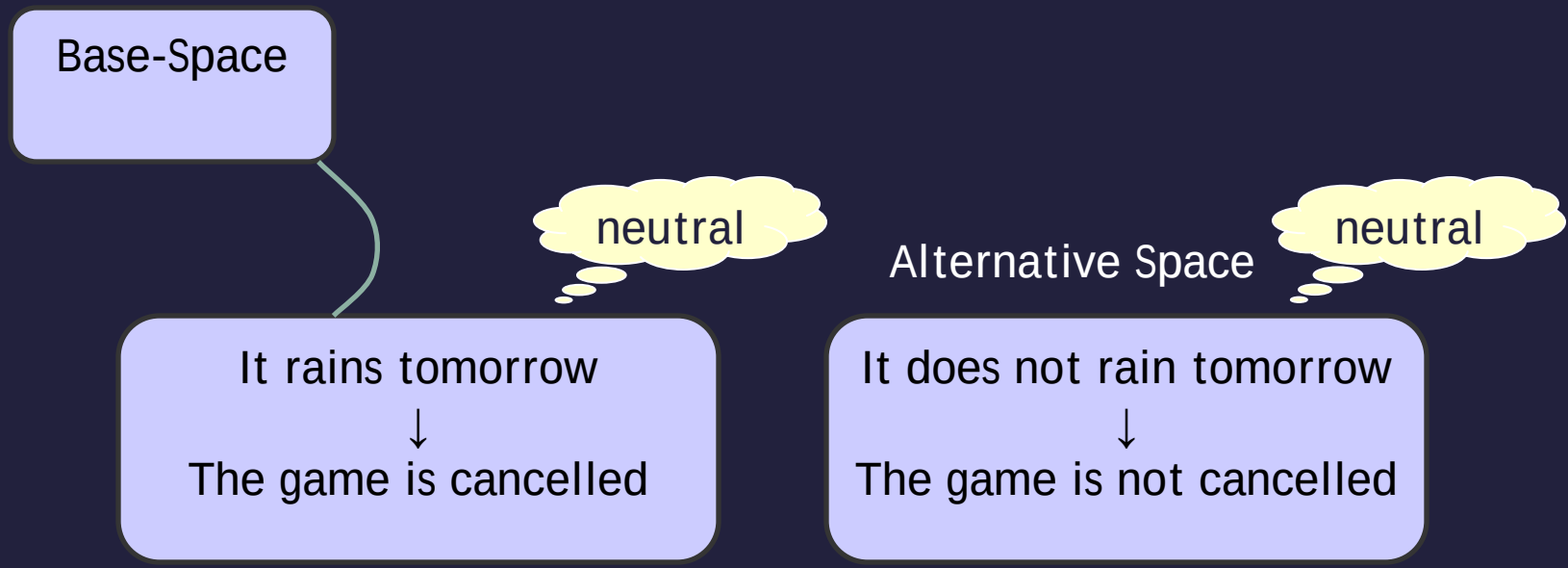
Case Study: English Conditionals

If it *rains* tomorrow, the game *will be* cancelled.

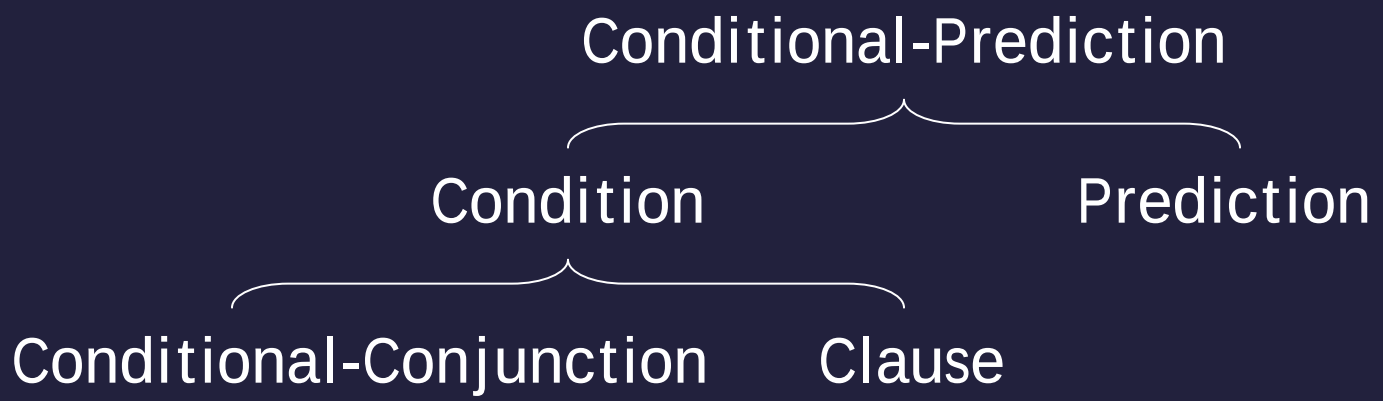
backshifting



Predictive Conditionals

(Dancygier & Sweetser, 2004.)

Game Plan



- Mental spaces are constructed compositionally
- The conjunction, the tense of verb in the clause, the time reference of the prediction combine to determine the space that is built

Representing Conditions

SCHEMA **Conditional-Schema**

SUBCASE OF Compressed-Mental-Space

ROLES

epistemic-stance

premise: Predication

conclusion: Predication

ums: **Conditional-Space**

CONSTRAINTS

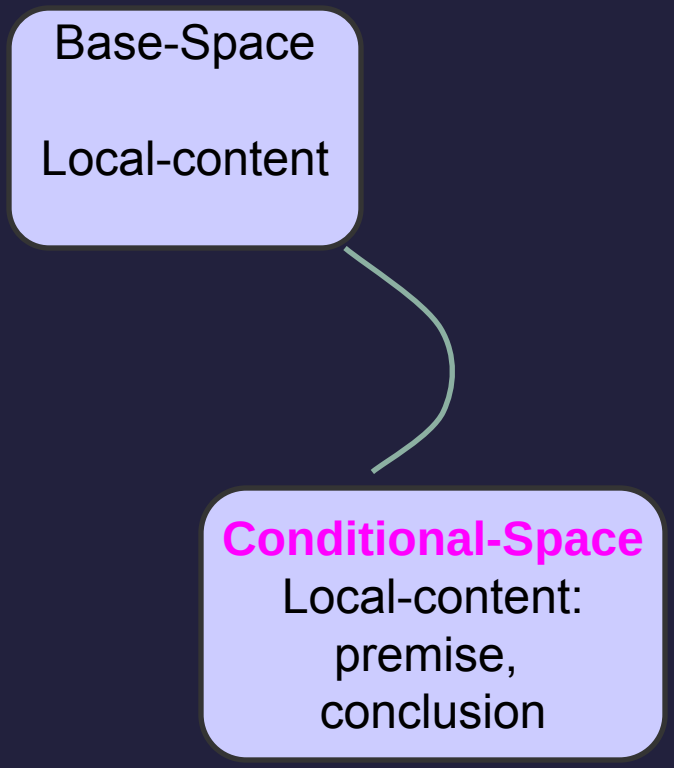
epistemic-stance ↔ ums.epistemic-stance

premise ↔ ums.premise

conclusion ↔ ums.conclusion

Conditional Space

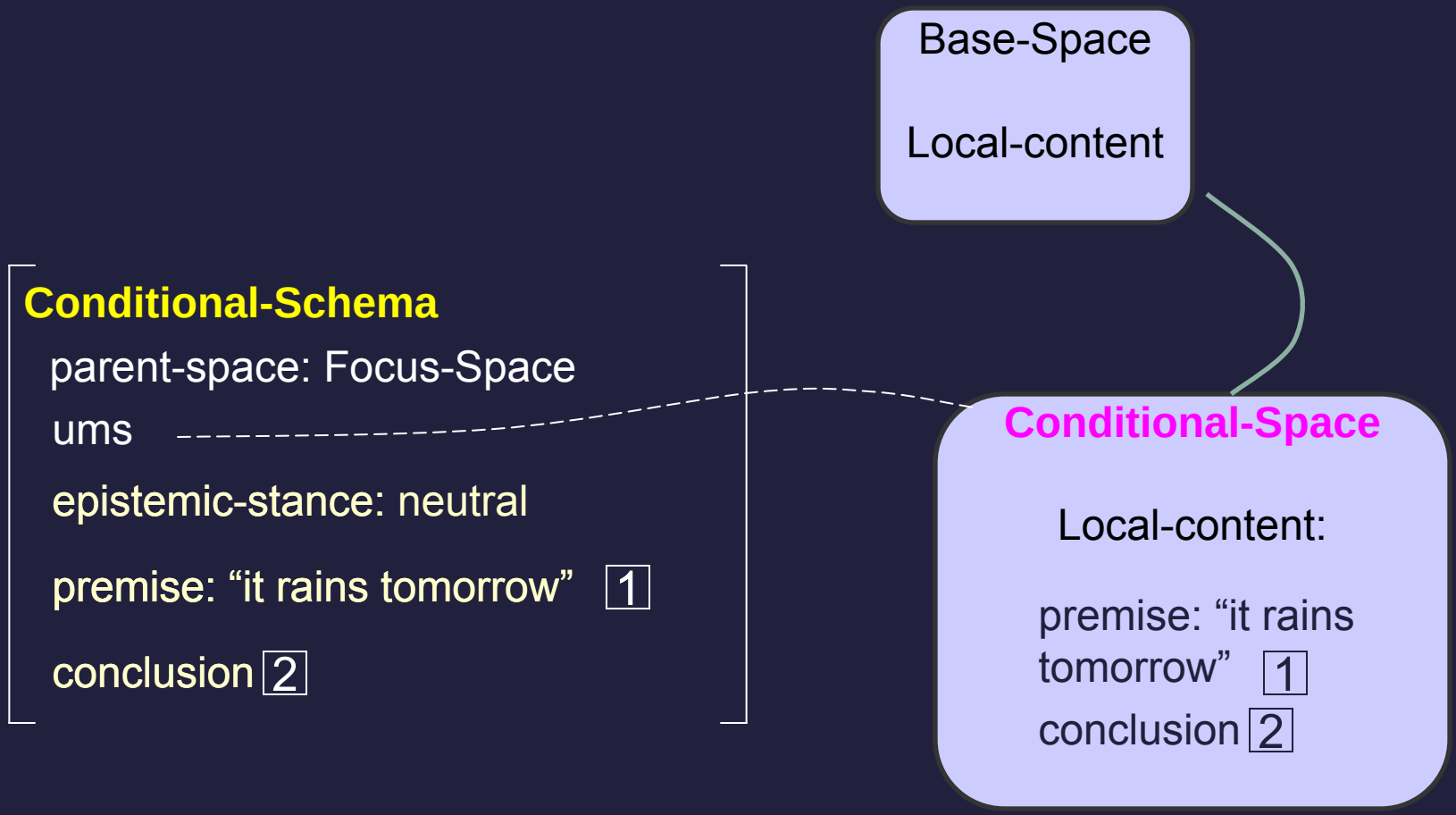
SPACE **Conditional-Space**
- SUBCASE OF Mental-Space
- ROLES
  - cms: Conditional-Schema
  - epistemic-stance
  - premise: Predication
  - conclusion: Predication
- CONSTRAINTS
  - premise.local-to ↔ self
  - conclusion.local-to ↔ self



The Condition Construction

CONSTRUCTION Condition
  SUBCASE OF Subordinate-Clause
  CONSTRUCTIONAL
    conj: Conditional-Conjunction
    cl: Clause
  FORM
    $conj_f$ meets cl_f
  MEANING: **Conditional-Schema**
    $self_m \leftrightarrow conj_m$.cs
    $self_m$.condition $\leftrightarrow cl_m$
    $self_m$.parent-space $\leftrightarrow$ focus-space

“if it rains tomorrow”

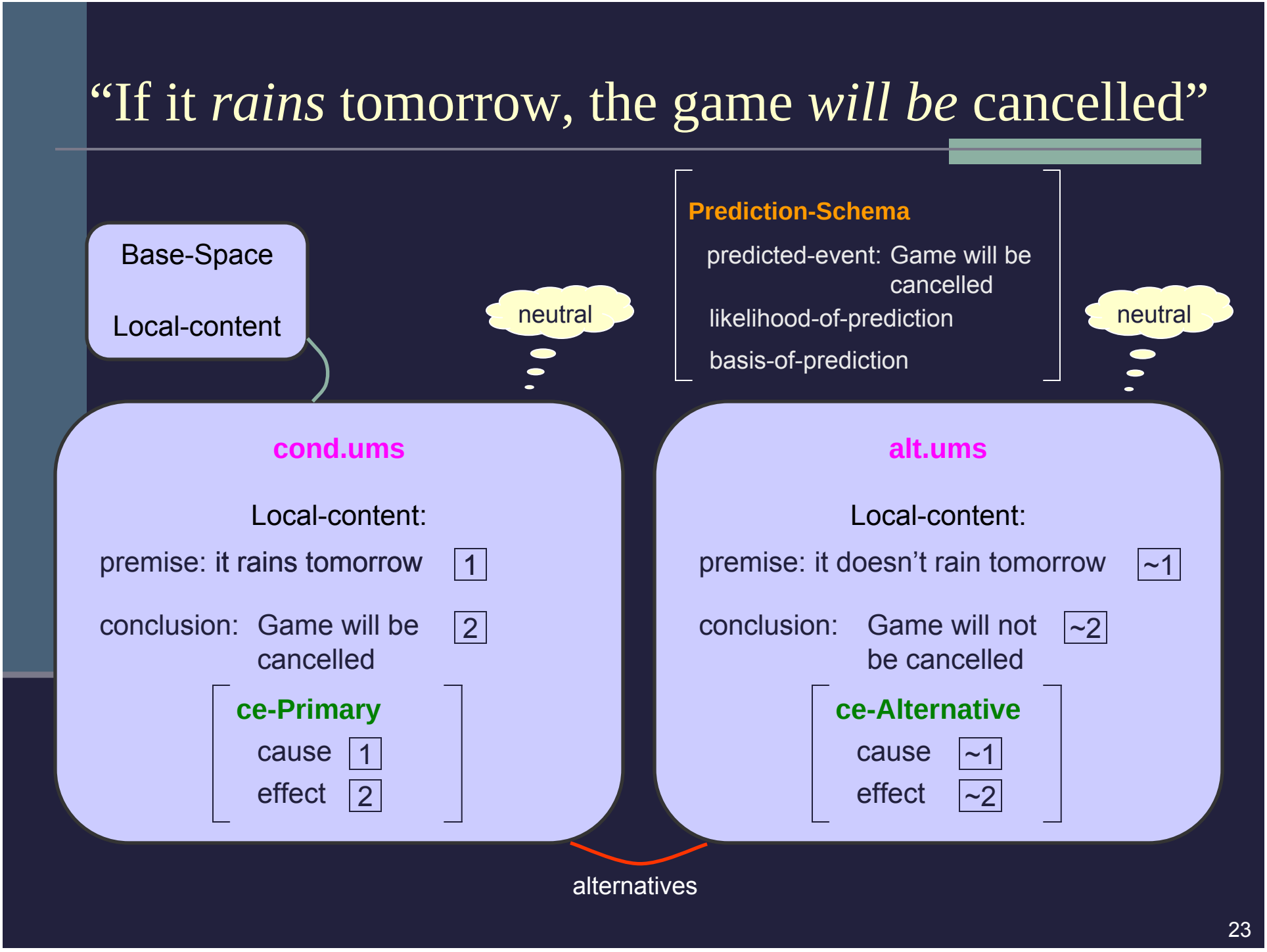


The Prediction Construction

SCHEMA **Prediction-Schema**
EVOKES Event AS e
ROLES
predicted-event: Predication
likelihood-of-predicted-event
basis-of-prediction: Predication
CONSTRAINTS
predicted-event.category ↔ e
predicted-event.time-location ← future

CONSTRUCTION Prediction
SUBCASE OF Clause
CONSTRUCTIONAL
tense ← relative-future (viewpoint-space)
MEANING:
EVOKES **Prediction-Schema** AS ps
ps.predicted-event ↔ $self_m$

"If it *rains* tomorrow, the game *will be* cancelled"



Conclusion

- Mental spaces have practical applications for Reference Resolution, Embedded Discourse, Q & A Systems, Dialogue Systems
- Formalization:
  - ECG provides a formalism for precisely writing down how mental spaces are specified by language
- Simulation and Inference:
  - Mental spaces correspond to separate threads of simulation, which are expanded as needed
  - CPRM provides a scalable way to perform simulation and inference